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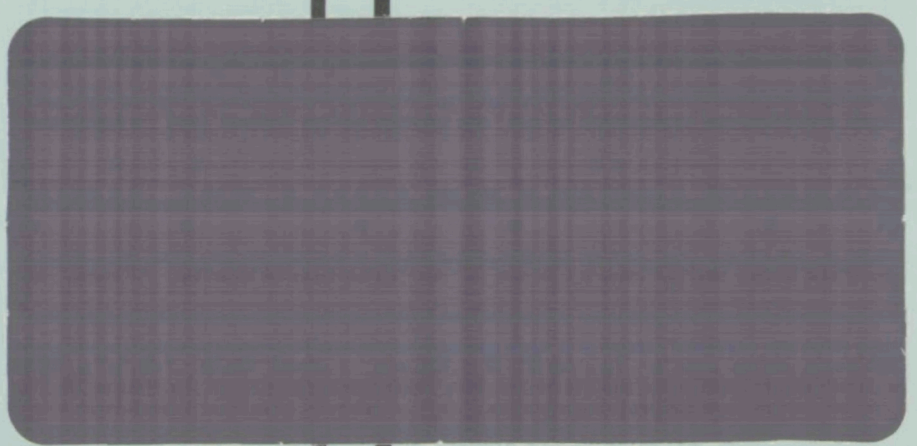

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Apollo

(NASA-CR-153880) PRETEST REPORT FOR THE 0.15-SCALE APOLLO FS-11 MODEL CANARD LOADS TEST IN THE NAA TRISONIC WIND TUNNEL (North American Aviation, Inc.) 20 p
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PRETEST REPORT FOR THE 0.15-SCALE APOLLO FS-11 MODEL CANARD LOADS TEST IN THE NAA TRISONIC WIND TUNNEL

NAS9-150

May 1964

Exhibit I, Paragraph 5.5

AVAILABLE TO NASA HEADQUARTERS ONLY

NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

FOREWORD

Tests of the 0.15-scale Apollo canard loads model will be conducted under NASA Apollo Contract NAS9-150. This report is associated with Paragraph 4.5 of Exhibit I.

This report was prepared by J. C. Snowden of the Experimental Aerodynamics Unit, Apollo Engineering, Space and Information Systems Division of North American Aviation, Inc.

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INTRODUCTION

This report contains pretest information pertaining to the forthcoming tests of the 0.15-scale FS-11 canard loads model in the North American Aviation Trisonic Wind Tunnel (TWT) scheduled to begin on July 6, 1964. Additional model information is presented in the structrual analysis report.

The primary objective of this test is to determine individual canard loading as a function of angle of attack and canard opening angles. A secondary objective will be to determine the steady-state pressure distributions over the canard surfaces and forward portion of the launch escape rocket motor for various angeles of attack. The test conditions will be in the Mach number range from 0.7 to 2.5 and the Reynolds number range from 8 to 17 million, based on the Command Module diameter. These conditions correspond to flight conditions at a canard deployment time of 11 seconds after abort, and at various abort altitudes.

The model configuration, model drawings, test program, and photographs are unclassified. Reduced, identified data will be CONFIDENTIAL.

I. MODEL DESCRIPTION

The 0.15-scale FS-11 model represents the forward section (from the full-scale station X_L 205.9 forward) of the launch escape rocket, including the canards. The canards are movable so that they may be positioned at deployment angles of 30, 60, 90, and 115 degrees. The deployment angles are measured in the plane perpendicular to the canard hinge line, where the 0° deployment angle is the fully closed position.

All major components are presented in this section and in Figure 1, along with nomenclature and dimensions. The four configurations to be tested are as follows:

Configuration	Component*	Basic FS-11 model with canard deployment of
1	E_{74}	30°
2	E_{75}	60°
3	E_{76}	90°
4	E_{77}	Fully deployed (115°)

Full-scale dimensions are as follows:

Escape Motor, E

Total Length	100.6 in.
Diameter	26.00 in.
Nose Angle	15.0 deg.
Nose Radius	2.0 in.
Length of Cylindrical Section of Canard	23.6 in.

*Note: E_{74}, E_{75}, E_{76}, E_{77} represent the rocket motor with the canards positioned at deployment angles of 30, 60, 90, and 115 degrees, respectively.

Length of Cone Section of Canard	23.698 in.
Leading Edge Span of Canard	10.166 in.
Trailing Edge Span of Canard	19.916 in.

The FS-11 is mounted on each of three bent stings used to cover an angle-of-attack range of -120 to +90 degrees. Bent stings with θ 's of 10, 50, and 90 degrees will be utilized. A typical installation in the TWT test section is shown in Figure 2.

II. MODEL INSTRUMENTATION

FORCE MEASUREMENT

Six-component force data will be taken on the left-hand canard looking forward by utilizing the NAA 2.5-inch MK-IX balance. Figure 1 shows the balance installation in the model.

No balance chamber pressure corrections will be made to the force data.

PRESSURE MEASUREMENT

The FS-11 model is instrumented with 34 surface static pressure taps to define pressure distributions over the canard surfaces and the rocket nose. Fifteen of these orifices are on the right-hand canard surface looking forward, and the remaining nineteen are distributed over the nose of the launch escape rocket. Figures 3 and 4 are instrumentation sketches showing all static tap locations, and Figure 5 is a complete instrumentation drawing.

The entire 34 pressures will be sensed by a bank of 34 differential transducers mounted in the sector pit below the floor of the tunnel. The model orifices are connected to the transducer bank by a combination of stainless-steel and flexible tubing of 0.065 ID and 0.093 OD.

III. TEST PROGRAM

With the first configuration installed in the tunnel, data will be taken for several angles of attack at a single Mach number according to the run schedule shown in Table 1. The test conditions to be used throughout the run schedule are shown in the following tabulation:

Test Conditions

Mach No.	Tunnel Re/ft	Dynamic Pressure (psf)	Settling Chamber Pressure (psi)	Run Time (sec)
0.7	9.1×10^6	1200	33	11
1.1	8.0×10^6	1450	25	19
1.5	8.0×10^6	1600	21	30
2.5	9.0×10^6	1600	43	32

A pitch pause sector sweep will be used for varying the angle of attack. The pause will be of 2-second duration for static pressure stabilization. Using the pitch pause system for the portion of the test that includes Mach numbers of 1.5 and 2.5, the procedure will be as follows: first, allowing a 4-second pause for flow stabilization and for taking the first point-of-pressure data; then, while taking force data, sweep 11 degrees at 4 deg/sec, pause 2 seconds for model pressure stabilization, and take the second point-of-pressure data. This process will continue until the sweep of 44 degrees is completed. The procedure for taking data at Mach 1.1 will be the same as for Mach 1.5 and 2.5, except that the sweep will be 22 degrees, with only two 2-second pauses. At Mach 0.7, two blows for each test condition will be required due to the short duration of the blow. After a 4-second stabilization, the model is to be swept 22 degrees at 4 deg/sec, then a pause for 2 seconds for pressure data. Repeating this blow will complete the 44-degree sweep.

Schlierens photographs will be taken during the 2-second pauses at supersonic Mach numbers. Installation photographs will be taken after each tunnel setup.

Table 1. Test Configuration and Run Schedule

Purpose of Test	Model Configuration	Mach No. 0.7	Mach No. 1.1	Mach No. 1.5	Mach No. 2.5	Model θ (degrees)	Angle-of-Attack Range (degrees)	Angle of Yaw Range (degrees)	Deployment Angle (degrees)
To Determine Canard Loads at Deployment	E_{74}	X	X	X	X	10	-2 to 42	0	30
	E_{75}	X	X	X	X				60
	E_{76}	X	X	X	X				90
	E_{77}	X	X	X	X				115
	E_{74}	X	X	X	X		2 to -42		30
	E_{75}	X	X	X	X				60
	E_{76}	X	X	X	X				90
	E_{77}	X	X	X	X				115
	E_{74}		X	X	X	50	38 to 82		30
	E_{75}		X	X	X				60
	E_{76}		X	X	X				90
	E_{77}								115

Table 1. Test Configuration and Run Schedule (Cont)

Purpose of Test	Model Configuration	Mach No. 0.7	Mach No. 1.1	Mach No. 1.5	Mach No. 2.5	Model θ (degrees)	Angle-of-Attack Range (degrees)	Angle of Yaw Range (degrees)	Deployment Angle (degrees)
To Determine Canard Loads at Deployment	E_{74}		X	X	X	50	-38 to 82	0	30
	E_{75}		X	X	X				60
	E_{76}		X	X	X				90
	E_{77}								115
	E_{74}	X	X	X	X	90	+78 to 90		30
	E_{75}	X	X	X	X				60
	E_{76}	X	X	X	X				90
	E_{77}	X	X	X	X				115
	E_{74}	X	X	X	X		-78 to -122		30
	E_{75}	X	X	X	X				60
	E_{76}	X	X	X	X				90
	E_{77}	X	X	X	X				115

IV. DATA REDUCTION

NOMENCLATURE

The symbols used in this test are as follows:

Body Axis System

C_N	Normal force coefficient
C_Y	Side force coefficient
C_A	Axial force coefficient
C_ℓ	Rolling moment coefficient about the x axis
C_m	Pitching moment coefficient about the y axis
C_n	Yawing moment coefficient about the z axis

Canard Axis System

C'_N	Normal force coefficient
C'_Y	Side force coefficient
C'_A	Axial force coefficient
C'_l	Rolling moment coefficient about the A axis
C'_m	Pitching moment coefficient about the Y axis
C'_n	Yawing moment coefficient about the N axis
$\frac{x_{cp}}{D}$ (N)	Chordwise center of pressure measured from origin of canard axis system along A axis
$\frac{x_{cp}}{D}$ (y)	Spanwise center of pressure measured from origin of canard axis system along y axis

General

α	Angle of attack, degrees
ϕ	Pressure instrumentation angle, measured from the top of the model, clockwise looking forward, degrees
δ_c	Canard deployment angle, 0 when canard closed, degrees
θ	Angle between the model axis of symmetry and the sector
q	Dynamic pressure, psf
S	Model reference area, in.^{2}
D	Model reference length, in.
D'	Rocket motor diameter, in.

Constants

Reference area, S = 419.097 in.^{2}
Reference length, D = 23.100 in.

The axis systems are defined in Figure 6.

FORCE DATA

Standard data reduction methods shall be used to provide body axis data for the balance mounted canard. The balance axis data shall be transformed to canard axis coefficients, defined as follows:

Canard transformation equations for one canard deployment angle

$$C'_N = -v_3 C_N + v_2 C_Y - v_1 C_A$$

$$C'_Y = -u_3 C_N + u_2 C_Y - u_1 C_A$$

$$C'_A = -w_3 C_N + w_2 C_Y - w_1 C_A$$

$$C'_\ell = w_3(C_n - y_o C_A - x_o C_Y) + w_2 (C_m + z_o C_A - x_o C_N) + w_1 (C_\ell + z_o C_Y + y_o C_N)$$

$$C'_m = u_3 (C_n - y_o C_A - x_o C_Y) + u_2 (C_m + z_o C_A - x_o C_N) + u_1 (C_\ell + z_o C_Y + y_o C_N)$$

$$C'_n = v_3 (C_n - y_o C_A - x_o C_Y) + v_2 (C_m + z_o C_A - x_o C_N) + v_1 (C_\ell + z_o C_Y + y_o C_N)$$

where v_1 is the direction cosine of the N axis with respect to the x axis.

v_2 is the direction cosine of the N axis with respect to the y axis.

v_3 is the direction cosine of the N axis with respect to the z axis.

w_1 is the direction cosine of the A axis with respect to the x axis.

w_2 is the direction cosine of the A axis with respect to the y axis.

w_3 is the direction cosine of the A axis with respect to the z axis.

u_1 is the direction cosine of the y axis with respect to the x axis.

u_2 is the direction cosine of the y axis with respect to the y axis.

u_3 is the direction cosine of the y axis with respect to the z axis.

x_o is the transfer dimension in the x direction of the origin of the canard axis system.

y_o is the transfer dimension in the y direction of the origin of the canard axis system.

z_o is the transfer dimension in the z direction of the origin of the canard axis system.

The variables u, v, and w and the transfer dimensions for various deployment angles are as follows for the direction cosine and transfer dimensions:

Direction Cosines

Canard Deployment Angle δ_c (deg)	u_1	u_2	u_3	v_1	v_2	v_3
30	0.1751	0.2030	0.9634	-0.00928	0.9793	-0.2023
60	0.3266	-0.2844	0.9006	0.06585	0.9575	0.2808
90	0.4197	-0.6872	0.5930	0.2051	0.7065	0.6773
115	0.4295	-0.8790	0.2072	0.3437	0.3690	0.8635

	Direction Cosines			Transfer Dimensions		
Canard Deployment Angle δ_c (deg)	w_1	w_2	w_3	x_o	y_o	z_o
30	0.9845	0.0265	-0.1733	10.7383	-2.4467	0.6885
60	0.9422	0.0330	-0.3334	10.7933	-3.0222	-0.2860
90	0.8844	0.1627	-0.4374	10.6502	-3.0661	-1.4093
115	0.8355	0.2996	-0.4606	10.4058	-2.6832	-2.2416

Note: All of the foregoing variables, i, u, w, x, y, and z, have been computed using a hinge line defined by the points:

P_T 1	P_T 2
x_1 = 347.66	x_1 = 371.830
y_1 = ±11.412	y_1 = ±3.384
z_1 = - 3.708	z_1 = -7.094

The final tabulated data should include the following: α, δ_c, C_N, C_A, C_Y, C_l, C_n, C_m, C'_N, C'_Y, C'_A, C'_ℓ, C'_m, C'_n, $\frac{x_{cp}}{D}$ (N), $\frac{x_{cp}}{D}$ (y), and C_p (for each tap).

PRESSURE DATA

The static pressure data will be reduced to coefficient form according to the equation

$$C_p = \frac{P - P_o}{q_o}$$

where C_p = Pressure coefficient at a given tap location, psi

P = Pressure at the given tap location, psi

P_o = Free stream static pressure, psi

q_o = Free stream dynamic pressure, psi

V. DATA TRANSMITTAL

Four copies of the final tabulated data are required and should be distributed as follows:

1. Letter of transmittal and two copies of the data (one copy reproducible), including Tunnel Run Log, to:

   North American Aviation, Inc.
   Space and Information Systems Division
   12214 Lakewood Boulevard
   Downey, California
   Attn: Mr. Edwin C. Allen, Dept. 696-710

2. Letter of transmittal and one copy of the data including Tunnel Run Log to:

   NASA Manned Spacecraft Center
   Apollo Spacecraft Project Office
   Office City, Gulf Freeway
   Houston, Texas
   Attn: Mr. Calvin H. Perrine

3. Letter of transmittal and one copy of the data including Tunnel Run Log to:

   NASA Manned Spacecraft Center
   Spacecraft Technology Division
   Aerodynamic Branch
   Houston, Texas
   Attn: Mr. W. C. Moseley, Jr.

North American Aviation, Inc., has a contractual obligation to provide NASA with a preliminary report containing tabulated data, thirty days after the completion of each test. In order to meet this requirement it will be necessary to have the complete set of data noted in 1., above, delivered to NAA not later than ten working days after the completion of the test.

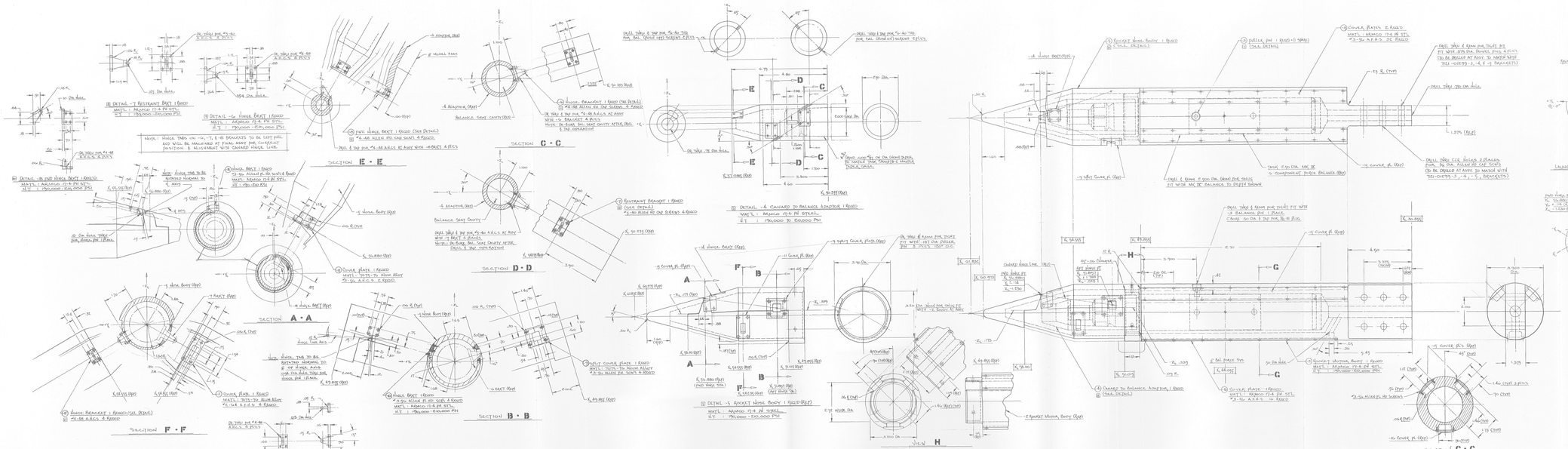
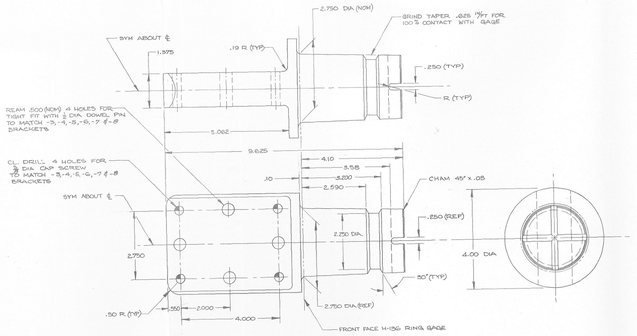
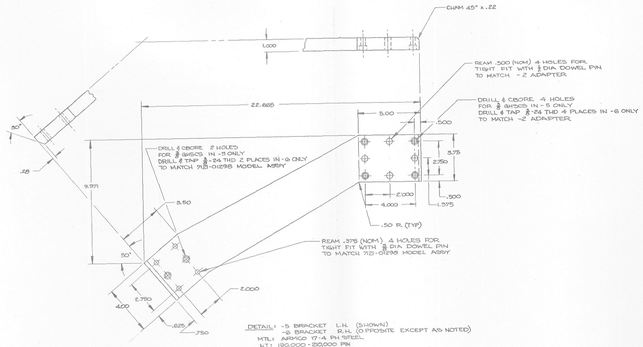


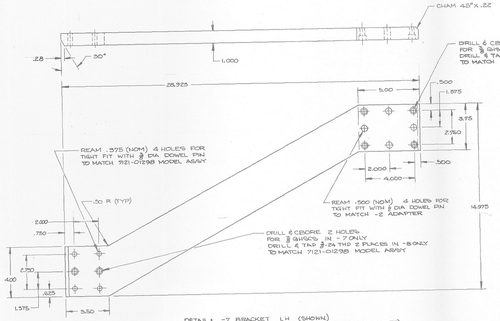
Figure 1. Model Assembly



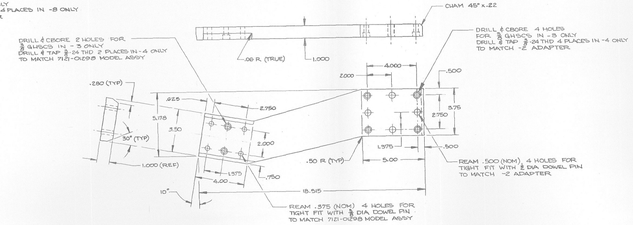
DETAIL: -2 ADAPTER
MTL: ARMCO 17-4 PH STEEL
H.T.: 190,000 - 210,000 PSI
(SCALE - FULL SIZE)


CHAM 45° x .22
1.000
.80°
.28
9.991
REAM .500 (NOM) 4 HOLES FOR TIGHT FIT WITH ½ DIA DOWEL PIN TO MATCH -2 ADAPTER
22.685
5.00
.500
DRILL & C'BORE 4 HOLES FOR ½ 8MS05 IN -5 ONLY DRILL & TAP ½-24 THD 4 PLACES IN -8 ONLY TO MATCH -2 ADAPTER
DRILL & C'BORE 2 HOLES FOR ½ 8MS05 IN -5 ONLY DRILL & TAP ½-24 THD 2 PLACES IN -8 ONLY TO MATCH 7121-01298 MODEL ASSY
3.375
2.250
2.000
4.000
1.575
.500
3.50
.50 R (TYP)
50°
REAM .375 (NOM) 4 HOLES FOR TIGHT FIT WITH ⅜ DIA DOWEL PIN TO MATCH 7121-01298 MODEL ASSY
2.000
2.750
.400
.625
.750

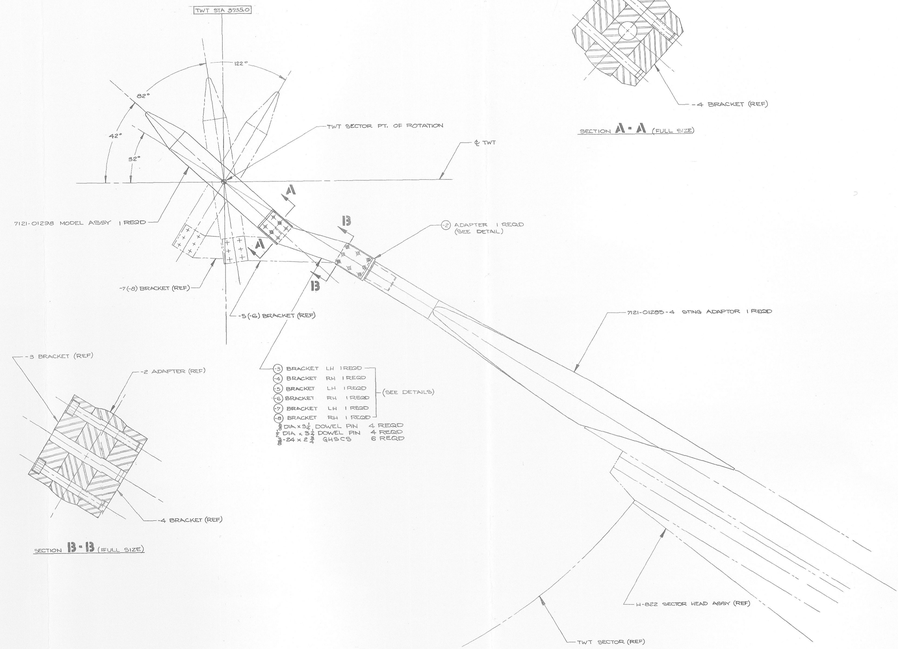
DETAIL: -5 BRACKET L.H. (SHOWN)
-8 BRACKET R.H. (OPPOSITE EXCEPT AS NOTED)
MTL: ARMCO 17-4 PH STEEL
H.T.: 190,000 - 210,000 PSI
(SCALE: ½ x SIZE)


CHAM 45° x .22
.28
30°
1.000
DRILL & C'BORE 4 HOLES FOR ½ 8MS05 IN -7 ONLY DRILL & TAP ½-24 THD 4 PLACES IN -8 ONLY TO MATCH -2 ADAPTER
28.325
5.00
.500
1.875
3.75
2.750
2.000
4.000
.500
REAM .375 (NOM) 4 HOLES FOR TIGHT FIT WITH ⅜ DIA DOWEL PIN TO MATCH 7121-01298 MODEL ASSY
REAM .500 (NOM) 4 HOLES FOR TIGHT FIT WITH ½ DIA DOWEL PIN TO MATCH -2 ADAPTER
.50 R (TYP)
2.000
.750
DRILL & C'BORE 2 HOLES FOR ½ 8MS05 IN -7 ONLY DRILL & TAP ½-24 THD 2 PLACES IN -8 ONLY TO MATCH 7121-01298 MODEL ASSY
14.975
2.750
.400
.625
1.575
3.50

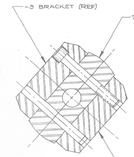
DETAIL: -7 BRACKET L.H. (SHOWN)
-8 BRACKET R.H. (OPPOSITE EXCEPT AS NOTED)
MTL: ARMCO 17-4 PH STEEL
H.T.: 190,000 - 210,000 PSI
(SCALE: ½ x SIZE)


CHAM 45° x .22
.28
.08 R (TRUE)
1.000
DRILL & C'BORE 4 HOLES FOR ½ 8MS05 IN -5 ONLY DRILL & TAP ½-24 THD 4 PLACES IN -4 ONLY TO MATCH -2 ADAPTER
DRILL & C'BORE 2 HOLES FOR ½ 8MS05 IN -5 ONLY DRILL & TAP ½-24 THD 2 PLACES IN -4 ONLY TO MATCH 7121-01298 MODEL ASSY
4.000
2.000
.500
.280 (TYP)
.925
5.178
3.50
2.750
3.375
2.750
2.000
50° (TYP)
1.575
.500
.50 R (TYP)
5.00
1.000 (REF)
1.575
.750
4.00
10°
18.515
REAM .500 (NOM) 4 HOLES FOR TIGHT FIT WITH ½ DIA DOWEL PIN TO MATCH -2 ADAPTER
REAM .375 (NOM) 4 HOLES FOR TIGHT FIT WITH ⅜ DIA DOWEL PIN TO MATCH 7121-01298 MODEL ASSY

DETAIL: -3 BRACKET L.H. (SHOWN)
-4 BRACKET R.H. (OPPOSITE EXCEPT AS NOTED)
MTL: ARMCO 17-4 PH STEEL
HT: 190,000 - 210,000 PSI
(SCALE: ½ x SIZE)

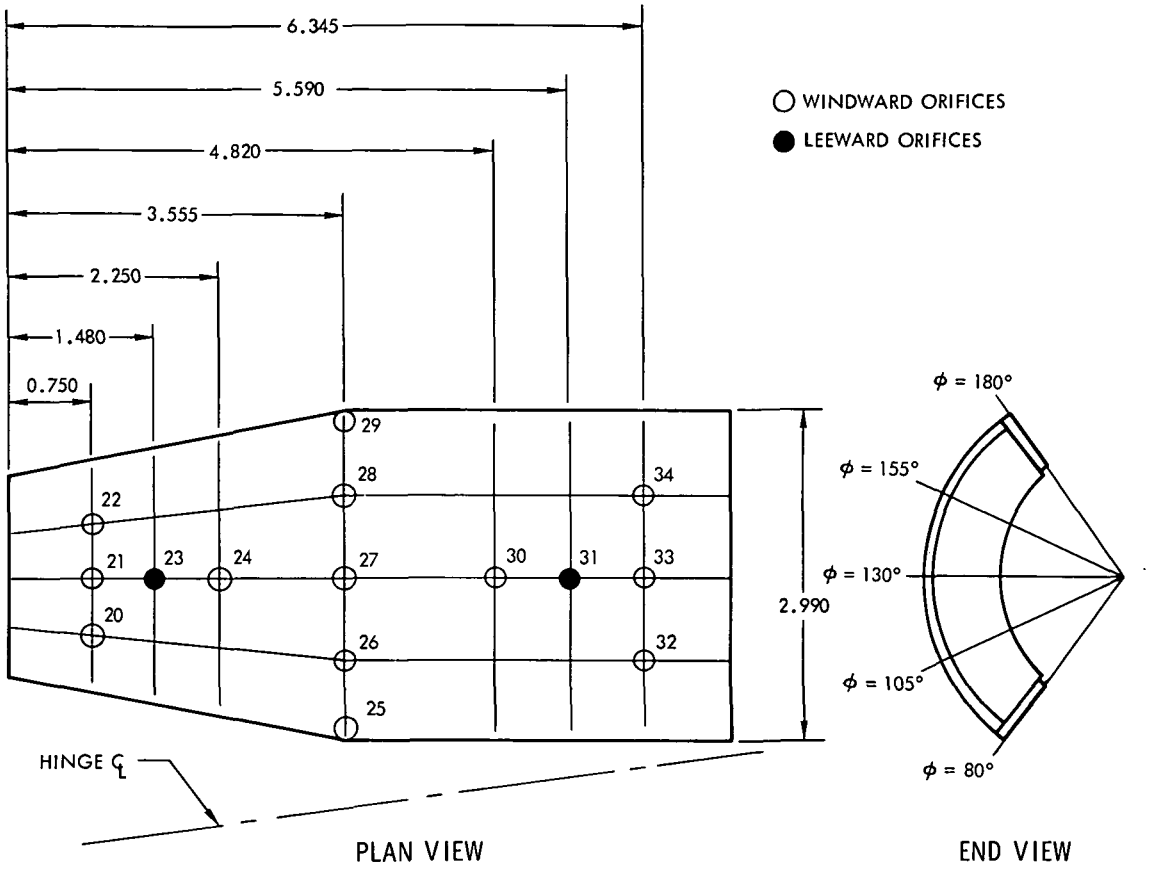


SECTION B-B (FULL SIZE)



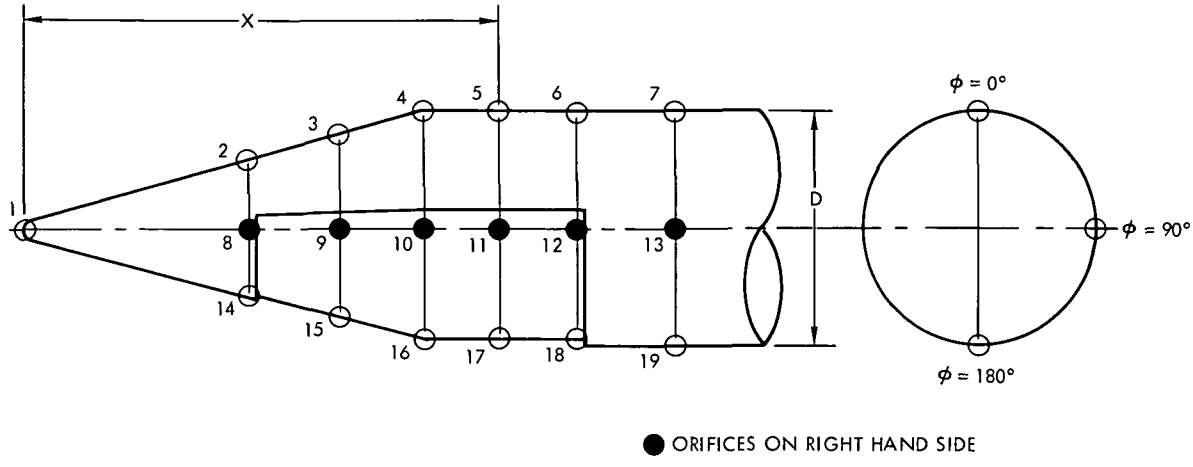
SECTION A-A (FULL SIZE)

Figure 2. Model Installation in TWT



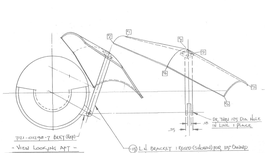
FRACTION OF CHORD AFT OF LEADING EDGE	φ				
	80	105	130	155	180
	CANARD ORIFICE NO.				
0.11		20	21	22	
0.21			23		
0.32			24		
0.50	25	26	27	28	29
0.68			30		
0.79			31		
0.89		32	33	34	

Figure 3. Canard Pressure Instrumentation Location and Designations

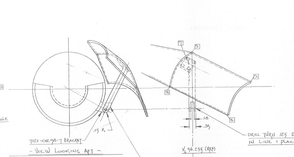


X/D	ϕ		
	0	90	180
	MODEL ORIFICE NO.		
0	1		
0.761	2	8	14
1.180	3	9	15
1.646	4	10	16
2.092	5	11	17
2.539	6	12	18
2.986	7	13	19

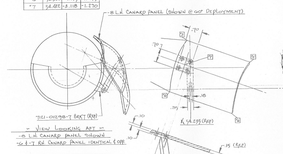
Figure 4. Rocket Pressure Instrumentation Location and Designations



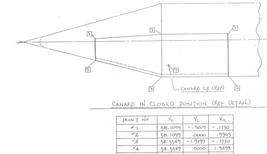
PT. NO	X_L	Y_L	Z_L
*A	55.941	-1.171	-1.349
*A	55.841	-1.784	-1.283
*B	51.982	-2.172	-.836
*B	51.889	-4.801	-.993
*F	48.982	-6.773	-2.096



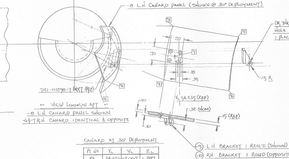
PT. NO	X_L	Y_L	Z_L
*D	49.883	-1.901	-1.851
*E	51.838	-2.408	-.958
*F	51.982	-2.172	-.836
*G	47.384	-4.179	-1.493
*H	46.882	-3.918	-1.730



PT. NO	X_L	Y_L	Z_L
*B	54.600	-1.932	-1.435
*A	55.385	-2.383	-1.256
*E	51.068	-2.662	-.896
*D	52.050	-4.960	-1.266
*F	48.981	-3.093	-1.861

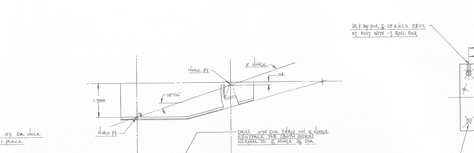


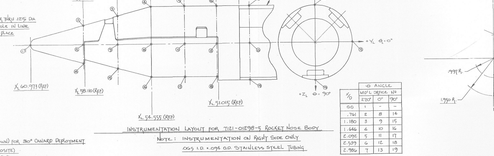
POINT NO	X_L	Y_L	Z_L
*1	58.005	-1.9011	-.1730
*2	58.1093	-.0000	-.9340
*3	54.1549	-1.9011	-.7330
*4	58.1549	.0000	1.9499
*5	51.0149	-1.9011	-.3385
*6	51.0150	.0000	1.1499
*7	54.1550	-1.9011	1.9375



CANARD AT 70° DEPLOYMENT

PT. NO	X_L	Y_L	Z_L
*B	54.600	-1.932	-1.435
*G	54.540	-2.061	-.891
*A	55.385	-2.383	-1.256
*E	51.068	-2.662	-.896
*D	52.050	-4.960	-1.266
*F	48.981	-3.093	-1.861





∠ ANGLE	
WITH +Z AXIS	ON
0.0	1
.764	2
1.180	3
1.486	4
2.092	5
2.529	6
2.986	7

∠ ANGLE WITH +Z AXIS	ON
0°	1
5°	8
9	9
10	10
11	11
15	12
13	13

DRILL .201 DIA THRU AND C'BORE .109 DIA X .060 DEEP FOR AN3212A-4P FLUSH SCREW AS REQ'D. CHAMFER TO CLEAR RADIUS
(3 PLACES EQUALLY SPACED)
DRILL .201 DIA THRU AND C'BORE .109 DIA X .060 DEEP FOR AN3212A-3P FLUSH SCREW AS REQ'D. CHAMFER TO CLEAR RADIUS
(2 PLACES EQUALLY SPACED)
DRILL .201 DIA THRU AND C'BORE .109 DIA X .060 DEEP FOR AN3212A-4P FLUSH SCREW AS REQ'D. CHAMFER TO CLEAR RADIUS
(2

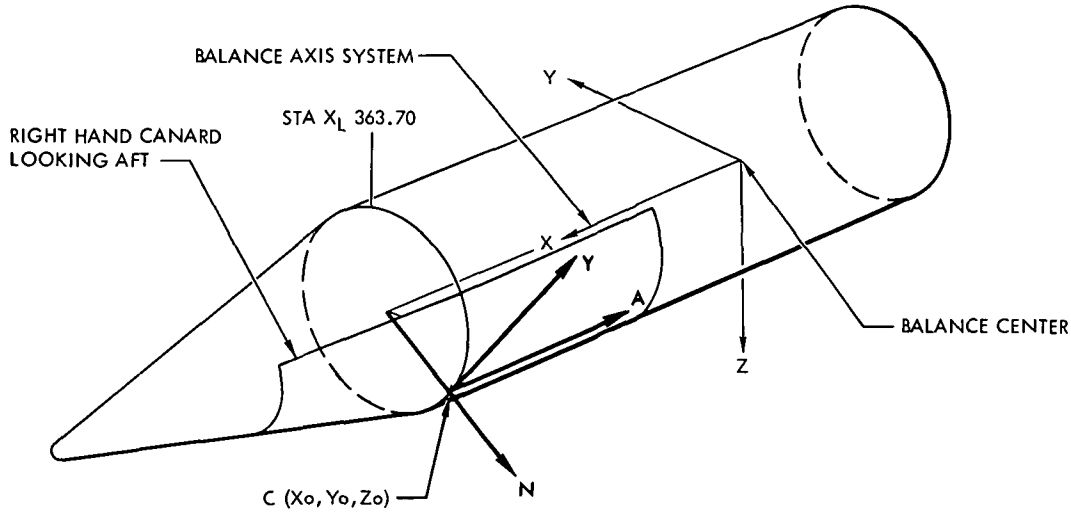


Figure 6. Axes Definitions